RASHTRIYA ISPAT NIGAM LIMITED

VISAKHAPATNAM STEEL PLANT

DEPARTMENT

STEEL MELT SHOP (SMS) 1

TOPIC

OPTIMISATION OF FERRO-ALLOYS IN STEEL MAKING

DURATION

29th APRIL, 2024 – 25th MAY, 2024

UNDER THE GUIDANCE

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THIS PROJECT IS SUBMITTED BY:

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RINL TRAINING PROJECT ID: **100028607**

CERTIFICATE

This is to certify that this project report entitled **"** ***OPTIMISATION OF FERRO-ALLOYS IN STEEL MAKING*****"** submitted to RINL,

VISAKHAPATNAM STEEL PLANT, is a Bonafide record to work done by: -
SANCHIT SINGH.

Students of Department of Metallurgical and Materials Engineering, under the supervision and great guidance of ***Mr. K Anil Kumar (DGM(O), SMS1, VSP, RINL)*** from 29-04-2024 to 25-05-2024.

Date:

……………………………………

(Seal and Signature of the Guide)

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Abstract

Visakhapatnam Steel Plant (VSP) is the first shore based integrated steel plant in India producing high-quality value-added steel. Producing 5.77 million tons hot metal, 5.27 million tons of crude steel and 5.52 million tons saleable steel, 5.52 million tons liquid steel during 2021-22 fiscal. Steel Melting Shop is one of the major departments of VSP where the production of steel by refining of hot metal (Pig iron) takes place.

Steel making through BOF route is still a predominant process as compared to EAF and Induction Furnace route. More than 60% of World liquid steel production comes from BOF route only. Steel making is autogenous processes due to oxidation of silicon which releases tremendous amount of heat that can be utilized and balanced by scrap and iron ore addition. Due to higher price of scrap and scarcity of lump iron ore in the world an alternate resource, iron ore fines in the form of sinter, may be used as a substitute coolant in the steel making process.

In this project we study the Optimisation of ferro alloy in steel making. Ferroalloys have lower melting ranges than the pure elements and have lower density hence can be incorporated more readily in the liquid steel than the pure elements. Ferroalloys are added to liquid steel to carry out the de-oxidation process of removal of excess oxygen (02) from the liquid steel. They have high affinity for 02 and form oxides in the form of slag. Aluminum (AI) is being used as a deoxidizing element in steels for more than 100 years. Deoxidation of steel with Al is common practice today.

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

1)Introduction to VSP

Visakhapatnam steel plant strikes every one with a tremendous sense of awe, wonder and amazement as it presents a wide array of excellence in all its facets in scenic beauty, in technology, in workforce, in management and in product quality. On the coast of Bay of Bengal and by the side of scenic Gangavaram beach, have risen tall and huge structures of technological architecture, the Visakhapatnam Steel Plant. But the vistas of excellence do not rest with the inherent beauty of location over sophistication of technology-they march ahead parading one aspect after another.

The decision of the Government of India to set up an integrated steel plant at Visakhapatnam was announced by then Prime Minister Smt. Indira Gandhi in Parliament on 17th January 1971 by the Prime Minister Visakhapatnam steel plant. The first coastal based integrated steel plant of India is located, 16km west of city of destiny i.e., Visakhapatnam, bestowed with modern technologies, VSP has an installed capacity of 3 million Tonnes per annum of liquid steel and 2.656 million tons of saleable steel. At VSP there is emphasis on total automation, seamless integration and efficient up gradation, which result in wide range of long and structural products to meet stringent demands of discerning customers with India & abroad. VSP product meet exalting international Quality Standards such as JIS, DIN, BIS, BS etc.

VSP has become the first integrated steel plant in the country to be certified to all the three international standards for quality (ISO -9001), for Environment Management (ISO-14001) & for Occupational Health & Safety (OHSAS-18001) the certificate covers quality systems of all operational, maintenance, service units besides purchase systems, Training and Marketing functions spreading over 4 Regional Marketing offices, 20 branch offices & 22 stock yards located all over the country .

V SP by successfully installing & operating efficiently Rs.460 crores worth of pollution and Environment control Equipment's and converting the barren landscape more than 3 million plants has made the steel plant, steel Township and surrounding areas into a heaven of lush greenery. This made steel Township a greener, cleaner and cooler place, which can boast of 3 to 4^{0}c lesser temperature even in the peak summer compared to Visakhapatnam city.

VSP exports Quality Pig Iron & Steel products Sri Lanka, Myanmar, Nepal, Middle East, USA & South East Asia (Pig Iron). RINL-VSP was awarded "Star Trading House" status during 1997-2000. Having established a fairly dependable export market, VSP plans to make a continuous presence in the export market.

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

1.1) BACK GROUND:

The Government of India decided to establish integrated steel plants in Public Sector at Visakhapatnam (AP) and Hosket (Karnataka) besides a special steel plant at Salem (Tamil Nadu).

The announcement was made in the parliament on 17th April' 1970 by the then Prime Minister of India late Smt. Indira Gandhi. A site was selected near Bala Cheruvu creek near Visakhapatnam city by a committee set up for the purpose, keeping topographical features.

Seeds were thus sown for the construction of a modern & sophisticated steel plant having annual capacity of 3.4 million tons of hot metal.

The construction of the plant started on I st February 1982.Government of India formed a new company called Rashtriya Ispat Nigam Ltd. (RINL) on 18th Feb'82 and transferred the responsibility of constructing, commissioning &operating the plant at Visakhapatnam from Steel Authority of India Ltd.to RINL.

The rationalized concept was based on obtaining the maximum output from the equipment's already installed, planned /ordered for procurement and achieving higher levels of operational efficiency and labor productivity. Thus, the plant capacity was limited to 3 million tons of Liquid steel per annum.

1.2) VSP TECHNOLOGY: STATE-OF -THE -ART:

❖ 7meter tall coke Oven Batteries with coke dry quenching

❖ Biggest Blast Furnace in the country

•e Bell —less charging system in Blast Furnace

❖ 100% slag granulation at the BF Cast House

❖ Suppressed combustion-LD gas recovery

system

❖ 100%continous casting of liquid steel

❖ "Temp core" and "Stemler" cooling process in LMMM & WRM respectively

• Extensive waste heat recovery systems

❖ Compressive pollution control measures

1.3) MAJOR SOURCES OF RAW MATERIALS:

Raw material linkages

The steel plants getting its supply of iron ore-lumps and fines from the Baila Dilla deposits in Madhya

Pradesh, SMS grade lime stone from Badarpur in MP, blast furnace grade lime stone from the

Kotin-Sonor deposits in MP. 20% of cocking coal requirements will be met by important through the Visakhapatnam harbor while the balance will come from the Bengal-Bihar area coal for power generation will come from Talcher in Orissa. And also, same raw materials are import from different places, which are shown in below table

Table 1.1

RAW MATERIAL SOURCES	SOURCE
Iron Ore Lumps & Fines	Baila Dilla, MP
BF Lime Stone	Jaggayyapeta , AP
SMS Lime Stone	UAE
BF Dolomite	Madharam, AP
SMS Dolomite	Madharam, AP
Manganese Ore	Chipurupalli, AP
Boiler Coal	Talcher, Orissa
Coking Coal	Australia
Medium Coking Coal	Gidi/Swan/Rajarpa /Kargali

1.4) WATER SUPPLY:

Operational water requirement of 36 MGD is being met from the Yeleru Water supply Scheme.

The total water requirements in steel plant & township were estimated at 70 MGD (13,280 M^3/hr.) at 3MT stage. However, present consumption is about 19 MGD (3600 M^3/hr.) in plant and 3 MGD (567 M^3/hr.) in township. Evaporation losses are 5 MGD (945 M^3/hr.) i.e., total 27 MGD (5100 M^3/hr.). This water is supplied to the Kanithi Balancing Reservoir through the YELERU CANAL or from Godavari

River. There are 5 pumps installed at Godavari Pump House to pump 85 million gallons of water into Yeleru canal.

1.5) POWER SUPPLY:

Operation water requirement of 180-200 MW is being met through Captive Power Plant. The capacity of the power plant is 286.5 MW. VSP is exporting 60 MW power to APSEB.

A peak construction power requirement was about 12 MVA. This was arranged from the Gajuwaka substation of APSEB at 33KV.

The plant has captive power generation unit consists of 3nos turbo generators, each having 60MW capacity. An additional requirement of operational power around 150MVA is being met from the APSEB grid. Operational power supply is initially at 220KV, which are subsequent stepped down to

400KV

1.6) MAJOR UNITS:

Table 1.2major units

DEPARTMENT	ANNUAL CAPACITY('OOOT)	UNITS (3.0 MT stage)
Coke Ovens	2,261	3 Batteries of 67 Ovens & 7 meters Height
Sinter Plant	5,256	2 sinter Machines of 312 Sq. meter. Grate area each
Blast Furnace	3,400	2 Furnaces of 3200 Cu. meter. Volume each
Steel Melt Shop	3,000	3 LD Convertors of each of 133 Cu. meter. Volume and six strand bloom casters
LMMM	710	4* Strand finishin mill
WRM	850	4* 10 strand finishing mill
MMSM	850	6 strand finishin mills

1.7) MAIN PRODUCTS OF VSP:

Table 1.3

Steel products	By-Products	Others
Angels	Nut Coke	Granulated Slag
Billets	Coke Dust	Lime Fines
Channels	Coal Tar	Ammonium Sul hate
Beams	Anthracene	
Squares	HP Naphthalene	
Flats	Benzene	
Rounds	Toluene	
Re-bars	Xylene	
Wire Rods	Wash Oil	

1.8) Modern Technology in VSP:

In Visakhapatnam steel plant modern technology has been adopted in many areas of production, some of them for the first time in the country. • 7-meter-tall coke ovens • elective crushing of coal • Dry quenching of coke

- On ground blending of sinter base mix
- Conveyor charging and bell less top for blast furnace
- Cast house slag granulation for blast furnace • 100% continuous casting of liquid steel
- Gas expansion turbine for power generation, utilizing blast furnace top gas pressure • Hot metal desulphurization
- Extensive treatment facilities of effluents for ensuring proper environment protection • Computerization for process control Sophisticated high speed and high production rolling mills

1.9) Major Plant Facilities:

The production facilities in the Visakhapatnam steel plant are most modern amongst the steel industry in the country. The know-how and the technology have been acquired from different parts of the world from the reputed and established sources. Some of the novelties of the Visakhapatnam steel plant are:

- 7meter height coke ovens of VSP are the tallest so far built in the country. Dry quenching of coke has been adopted which will not only improve the quality of coke and economics of coke production, but also contribute significantly to the reduction of environment pollution
- Base mix yard for sinter plant introduced for the first-time country helps in excellent blending of the feed material to the sinter machine and production of consistent good quality sinter.
- 3200 cubic meters two blast furnaces with bell less top charging equipment and 100% cast house slag granulation. The granulation of the entire molten slag arising at the furnace cast house avoids the need to transport molten slag and optimizes utilization of slag.
- 100% continuous casting of liquid steel in to blooms result in less and better quality of blooms.
- The VSP have three sophisticated and large rolling mills with the latest features of automation and optimization.
- The operations of blast furnace, steel melting shop and rolling mills have been entirely computerized to ensure consistent quality and efficient performance.

2)Major Departments in VSP

Visakhapatnam steel plant having different departments,

They are

i. Raw Material Handling Plant (RMHP)
ii. Coke Ovens & Coal Chemicals Plant (CO& CCP)
iii. Sinter Plant
iv. Blast Furnace (BF)
v. Steel Melting Shop (SMS)
vi. Continuous CastingDepartment
vii. Rolling Mills:

2.1) Raw Material Handling Plant (RMHP):

VSP annually requires quality raw materials viz. Iron Ore, fluxes (Limestone, Dolomite), coking and non- coking coals etc. to the tune of 12-13 million tons for producing 3 million tons of Liquid Steel. To handle such a large volume of incoming raw materials received from different sources and to ensure timely supply of consistent quality of feed materials to different departments, Raw Materials

Handling Plant serves a vital function. This unit is provided with elaborate unloading, blending, stacking & reclaiming facilities viz. Wagon Tipplers, ground & Track Hoppers, Stock Yards, Crushing, Plants, Vibrating Screens, Single/Twin Boom Stackers, Wheel on Boom and Blender Reclaimers. In VSP, peripheral unloading has been adopted for the first time in the country.

Fig 2.1 RMHP

2.2) Coke Ovens & Coal Chemicals Plant (CO&CCP):

Coal is converted into coke by heating the prepared coal blend charge in the coke ovens in the absence of air at a temperature of 1000^0C-1050^0C for a period of 16/19 hours. The volatile matter of coal liberated during carbonization is collected in gas collecting mains in the form of raw coke oven gas passing through stand pipes and direct contact cooling with ammonia liquor spray. The gas cooled from 800^0C to 80^0C is drawn to Coal Chemical Plant by Exhauster. The residual coke is pushed out of the oven by pusher car through a guide into coke bucket. The red-hot coke is taken to coke dry cooling plant for cooling.

The main by-product in the process of coke making is crude coke oven gas and this has a lot of valuable chemicals. Coal Chemical Plant recovers Ammonia (NH3), Tar and Benzol from CO-Gas. The primary by-products from Crude CO Gas are Ammonium Sulphate (NH4)2S04, Crude Tar, Crude Benzol and cleaned coke oven gas. The cooled coke from CDCP (Coke Dry Cooling Plant) is separated into 3 fractions, BF Coke i.e., +25-70 mm, which is sent to Blast Furnaces, Coke Breeze i.e. +0-15 mm, which is sent to Sinter making and nut coke i.e., +15-25 mm, which is also used in the Blast Furnaces.

Facilities:

- There are 5 batteries, each having 67 ovens. . • The volumetric capacity of each oven is 41.6 m^3 . • Dry Coal charge [Oven is 32 tons.

Salient features:

- Largest and technologically unique Coke Oven Batteries in the country at the time of commissioning
- 7-meter-tall coke ovens batteries.
- 100% Dry Quenching of coke using Nitrogen gas.
- Power generation, from the waste heat recovered, at BPTS (Back Pressure Turbine Station).

Capacity:

- Production capacity (for 5 Batteries) — 3.600 Mt of BF coke per annum

Fig 2.2 Coke Ovens & Coal Chemicals Plant

2.3) SINTER PLANT:

Sintering is an agglomeration process of fine mineral particles into a porous mass by incipient fusion caused by heat produced by combustion within the mass itself. Iron ore fines, coke breeze, limestone and dolomite along with recycled metallurgical wastes are converted into agglomerated mass at the Sinter Plant, which forms 70-80% of iron bearing charge in the Blast Furnace. The vertical speed of sintering depends on the suction that is created under the grate. At VSP, two exhausters are provided for each machine to create a suction of 1500-1600 mm water column under the grate.

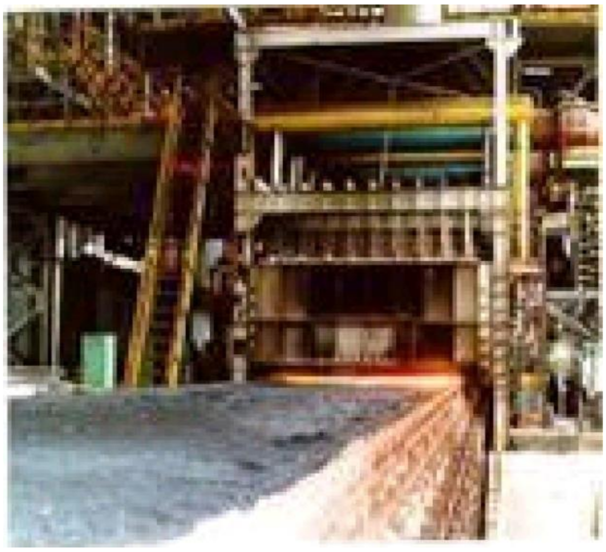

Fig 2.3

- Sinter Machine - l: 3.784 MT of Gross Sinter per annum (after Modernization)

Capacity:

Increased sinter grate area from 312 Sq.mtr to 378 Sq.Mtr of Sinter plant 1 on 3rd April 2023.

- Sinter Machine — 2: 2.85 MT of Gross Sinter per annum.
- Sinter Machine — 3: 3.511 MT of Gross Sinter per annum

2.4) Blast Furnace (BF):

Iron is produced in the Blast Furnace by smelting iron bearing materials with the help of coke and air. The solid charge materials like sinter, sized iron ore, coke etc. are charged in the vertical shaft of the Blast Furnace from top and hot air blast is blown through tuyeres located at the bottom. The oxygen present in hot air combines with the carbon of coke and generates heat and carbon monoxide (reducing agent). The reducing gases, while ascending upwards comes into contact with the descending charge materials. Eventually the charge gets reduced and hot metal, slag and BF gas are produced. Hot metal and slag are tapped from tap hole. The Blast Furnace gas which comes out from top of the furnace is cleaned and used as fuel in the plant.

Facility: Three Blast Furnaces of 3800 m^3 useful volume each.

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

Salient features:

BF-I & 2

- Upgraded useful volume is 3620 m^3
- New generation Paul-Wurth "Bell-Less" Top with conveyor charging
- BF Cooling elements (Cast Iron Staves & Copper Staves)
- High heat zone copper staves.
- Double compensator tuyeres, with PCI injection facility and extended tuyere platform.
- Circular type flat cast house with full castable runner system
- Hydraulic Drilling Machine, Mud Gun, Manipulators.
- Silencer to bin pressure relief.
- New scrubber with annular gap element for better gas cleaning.
- HMI based control room.
- Equipped with above burden temperature Probes.
- Automation with PLC in BF-I and PCS in BF-2.
- Pulverized Coal Injection system

BF-3

- New Generation Parallel Hopper Bell Less Top
- BF Cooling elements (Cast Iron Staves & Copper Staves)
- Flat Cast house Equipment (by TMT).
- INBA Slag Granulation system Annular Gap Scrubber
- Pulverized Coal Injection system
- Hot Stoves (internal combustion chamber)
- Automation with DCS

Capacity:

- BF-I daily production of 8100 tons on 15th Jan 2023
- 7.5 MT per Annum for shop
- 2.5 MT per Annum for BF- 2 & 3 each and 2.9 MT per Annum for BF-I

2.5) STEEL MELTING SHOP 1 (SMS 1)

Continuous Casting Department:

Steel is made in steel melting shop in the refractory lined vessels called LD Converters by blowing oxygen through the hot metal bath. While iron making is a reduction process, steel making is an oxidation process. The oxygen reacts with impurities like carbon, silicon, phosphorous, Sulphur etc. present in hot metal to produce steel. No external fuel is required as the silicon & carbon releases huge amount of heat energy. Also, the carbon reaction releases large quantities of gas rich in carbon monoxide along with huge amount of dust. The gases released from the converter are collected, cooled, cleaned and recovered for use as fuel in the steel plant. The entire molten steel at VSP is continuously cast at the radial type continuous casting machines resulting in significant energy conservation and better-quality steel. 100% Continuous casting on such a large scale has been conceived for the first time in India.

Facilities

Steel Melting Shop (SMS):

The Steel Melting Shop consists of two units, SMS-1 and SMS-2, equipped for efficient steel production.

SMS-1:

- Three 150-ton LD (Linz-Donawitz) converters with DOG House facility.
- Six 4-strand Continuous Bloom Casting (CBC) machines.
- One Injection Refining and Up-Temperature (IRUT) unit.
- One Ladle Furnace.

SMS-2:

- Three 150-ton LD converters.
- Three Ladle Furnaces.
- One 6-strand Continuous Billet-cum-Round caster.
- Two 6-strand Continuous Billet casters.
- One 5-strand Continuous Billet-cum-Round caster.
- Hot Metal Desulphurization Plant (HMDP).
- DOG House facility.
- RH Degasser.

Salient Features:

- 100% Continuous Casting of steel for improved efficiency.
- Converters with gas cooling, cleaning, and recovery systems for environmental sustainability.
- Computerized converter process control for better accuracy and consistency.

Capacity:

Combined annual capacity of 7.3 Million Tonnes (MT) of liquid steel as of 2024.

SMS-1:

- Original installed capacity: 3.0 MT of liquid steel and 2.82 MT of CC Blooms per annum.
- After modernization of all three converters, the capacity increased to 3.5 MT of liquid steel and 3.29 MT of CC Blooms per annum.

SMS-2:

- Annual capacity: 3.8 MT of liquid steel and 3.7 MT of CC Blooms/Rounds per annum from Converters-D, E, and F

Fig 2.5.1 SMS (LD)

Fig 2.5.2 CCD

2.6) Rolling mill

The four-zone combination type reheating furnace of 200 T/hour capacities (with front charging and side discharging) is equipped with radiant roof burners and microprocessor control for uniform heating of the billets. The gas and air recuperators are energy conservation measures in the reheating furnaces. All together there are 61 stands in the entire mill. The maximum rolling speed is 76 m/s. The mill is designed to roll low, medium and high carbon steels, low alloy steels and free cutting steels. The mill is equipped with retarded Stelmor lines for improving the quality of wire rods. Both very low carbon and very high carbon wire rods can be heat treated to improve the wire rod qualities. Mill also has temp core process of rapid water cooling.

The cast blooms from continuous casting department are heated and rolled in the three high speed and fully automated rolling mills namely Light & Medium Merchant Mill, Wire Rod Mill and Medium Merchant & Structural Mill, to produce various long products like Reinforcement bars, rounds, squares, flats, angles, channels, billets, wire rods etc. Technologies adopted at Rolling Mills include world-class Stelmor and Temp core processes.

Over View of Steel Melting Shop 1 (SMS 1):

Steel is an Alloy of Iron with Carbon upon I .8%. Hot metal produced in BFs contains impurities such as Carbon (3.5 — 4.24%), Silicon (0.4 — 0.5%), Sulphur (0.04 max) and Phosphorous (0.14 max) is not suitable as a common engineering material. To improve the quality the impurities are to be eliminated or decreased b Oxidation Process.

SMS 1 produces steel by using 3 top blowing Oxygen LD Converters (LD Stands for Linz & Danowitz two towns of Austria where this process was first adopted) and all Converter have Combined Blowing facilities in SMS-01. Each Converter have 150 tons to be capable of producing 3 million Tons of liquid steel annually. Besides Hot metal, Steel Scrap, Fluxes such as Calcined Lime or Dolomite from part of the charge to the converters.

99.5% pure Oxygen at 15 — 16Kg/cm2 pressure is blown in the converter through Oxygen lance having Convergent Divergent Copper Nozzles at the blowing end. Oxygen oxidizes the impurities present in the Hot Metal, which are formed as Slag with Basic Fluxes such as Lime. During the process heat is generated by Exothermic Reactions of Oxidation of Metalloids viz Si, Mn, P and Carbon temperature raises to 1700C enabling refining & Slag formation.

Different Grades of Steel of quantity can be made by this process by controlling the Oxygen blow or

Addition of various Ferro Alloys or Special Additives such as Fe-Si, Fe-Mn, Si-Mn, Coke Breeze, Aluminum etc. In required quantities while liquid is being tapped from the converter into a Steel Ladle. Converter / LD Gas produced as by product is used as a Secondary Fuel.

Technical Specifications of LD Converter:

3 LD Convertors in SMS. The characteristics of Convertor is:

Capacity	• 150 tons
Effective Volume	• 152.13 tons
Specific Volume	1.0 M^3/ton
Height of convertor	: 9100 mm
Diameter of convertor	• 7520 mm
Height/diameter Ratio (shell)	: 1.21
Tap to Tap time	• 50-55 min

Refractory Lining:
MgO based: (Sea Water Magnesia, MgO-C, Tar bonded Dolo bricks)

Oxygen Lance:

Copper tipped 6 Nos. Convergent — Divergent Nozzles symmetrically at 17.5 ^{0} to lance axis.

Characteristics of Oxygen Lance:

Lance Travel	: 16.0 m.
Oxygen working pressure	16 KSC
Water working pressure	: 12 KSCg
No. of Nozzles	:6
Water consumption	: 160 Cum/hr.
Oxygen flow rate	:450- 500 NM^3/min

CHARGE MATERIALS IN CONVERTER:

HOT METAL: {C: 4.3 Si: 0.3 - 0.6 Mn: 0.04 - 0.06%; S: 0.04%; P: 0.15 % Max} Scrap: {C: 0.2 %, P: 0.04%, Si: 0.15%} as coolant.

Lime: Cao: 90%, size: 10 — 25 mm.
1/0 (Iron ore) as coolant: Fe: 66-67%, SiO_2:0.9%, **Size**:15-60
Calcined Dolo: Cao: 35-40%, Mgo: 25 %

LIQUID STEEL & SLAG COMPOSITION

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

Liquid Steel Composition

Carbon	Silicon	Phosphoro	Sulphur	Manganese
0.04%	0.03%	0.02-0.03%	0.03%	0.02%

Slag Composition:

CaO	MgO	Basicity	SiO2	FeO	Wt of liq. Steel
50.10%	9.50%	2.72-3.0%	18.40%	18.20%	150 Tons

CONVERTOR GAS:

During blowing LD gas is generated. This is a very Poisonous Gas because its main component is Carbon Monoxide. LD gas cooling, cleaning and collection system comprises of tube bar-tube type skirt, gas cooling hood and stack, closed loop type gas cooling arrangement with fin fan cooler, impactor, gas duct, ID Fan change over valve, flare — stack, gas holder, etc. When the gas composition is acceptable, it is recovered and collected in gas holder. Unacceptable LD Gas is discharged through flare stack.

LD GAS COLLECTION SYSTEM: Gas collection with suppressed combustion.

LD GAS COOLING: Gas cooling with closed loop hot water pressurized cooling system.

COMPOSITION OF CONVERTOR GAS:

Yield	CV	CO	O2	H2	N2
71 Tonnes	1895 Kcal	70-80%	0.20%	1.2-2.4%	Rest

EQUIPMENT AND MAINTENANCE ACTIVITIES:

Mixer Shop:

- 2 Cranes (180 T / 63 T/20 T) EOT HTMC (Hot Metal Transfer car) Scrap Yard: 9.5 to Il T Scrap requires for each heat
- Transfer car
- Scrap weight bridge
- Scrap box.
- Magnetic EOT Crane

Slag Yard:

- Slag pot transfer car
- Slag Pot(16-18 M3 Capacity)
- 2 EOT Cranes for dumping into pits (4 Nos)
- Slag dump cars – Nos.

LP Bay:

- Horizontal ladle stand
- Vertical ladle stand
- Relining Pits
- Ladle Drier
- 3 EOT Cranes
- On line Drier with
- 26 Steel ladles

Maintenance activities:

- Lance Calibration
- Lance emergency lift checking.
- Gunniting Charge pad patching
- Mouth Ring Dropping

Introduction

Why we can't use iron directly?

- **Limited Applications:** Wrought iron's limitations meant structures like large bridges or buildings were difficult or impossible to create. Tools and weapons were less durable, impacting construction, agriculture, and warfare.
- **Labor Intensive:** Shaping iron required significant effort due to its properties. This made construction and tool-making slow and resource-intensive.
- **Weight Issues:** Buildings and structures made from bronze or wrought iron often needed to be thicker due to their lower strength, leading to heavier and bulkier designs.

What does steel accomplish?

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

 Limited Applications: Wrought iron's limitations meant structures like large bridges or buildings were difficult or impossible to create. Tools and weapons were less durable, impacting construction, agriculture, and warfare.

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Raw material for steel making

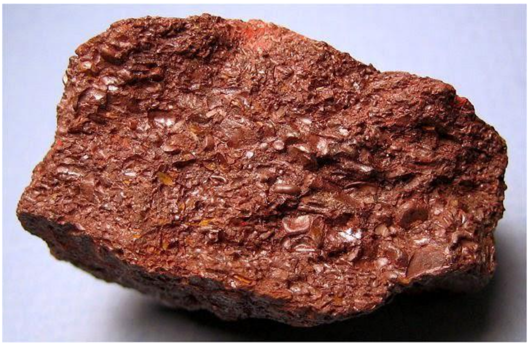
- Molten iron: It is obtained from blast furnace operations
- Scrap steel :

Internal Scrap Steel: This steel is generated inside the plant. Steel which does not comes under any specified grade is ysed as internal scrap steel

External Scrap Steel: This steel is imported from other sources out of the plant.

- Flux : Flux acts like a cleaning agent in steelmaking. It reacts with impurities in iron ore, forming a lighter slag that floats on top of the molten iron. This allows us to easily remove the slag, leaving cleaner molten iron for high-quality steel. Think of it like a strainer for unwanted bits in soup, ensuring a cleaner "broth" for making great steel. Flux like limestone and calcined dolomite are commonly used.

- Oxygen: 99.9% oxygen is used with a pressure of 16 bar and is blown using a water-cooled lance into the steel.
- Alloying elements like ferro-silicon, ferro-manganese, ferro-chrome and silico-manganese are used.



Iron ore

Flux(Limestone)

Scrap Steel

Basic steel making

Basic Oxygen Steelmaking: A High-Efficiency Process

Basic Oxygen Steelmaking (BOS) is a dominant method for primary steel production. Here's a breakdown of the key aspects:

- **Feedstock:** Molten, carbon-rich pig iron serves as the starting material.
- **Decarburization:** Pure oxygen is blown through the molten iron for about 20mins, making the conversion of excess carbon into carbon monoxide (CO) and carbon dioxide (CO_2) easy. During the process, metal and flux get mixed and forms an emulsion which helps inn refining. This reduces the overall carbon content, giving us steel.

- **Refractory Lining:** The vessel containing the reaction is lined with refractory materials like calcium and magnesium oxide. These materials can withstand the extreme temperatures and corrosive nature of the molten metal and slag (impurity byproducts).
- **Impurity Removal:** The process is carefully controlled to ensure the removal of unwanted elements like silicon and phosphorus, leading to a cleaner steel product.

Blow of oxygen

Oxygen is blown at a pressure of 16 bar into the steel using a water cooled lance . A three hoses pipe that is connected to a lance in which one hose supply cool water and second one takes out the hot water, and the third one is used to supply oxygen to the lance. 6 nozzles are there at the end of the lance, this part is generally made of copper and the pipe is made of mild steel. We can control the flow rate of the oxygen supply during lancing. The general height of lance is 6 meters

The blow is terminated when the gas flow reaches 40,000 or CO% in gas is less or equal to 50-55 % to achieve carbon content of 0.03-0.05 %.

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

Reblow

The major aim of reblow is to increase the temperature of the bath. To maintain the temperature to a the liquidous temperature for the process of casting, reblow is done.

The temperature is decreased due to the following reasons:

- Taping
- Transportation of the molten steel
- Addition of Ferro-alloys and Aluminium

Deoxidation

Deoxidation is a crucial step in steelmaking that removes excess oxygen from the molten iron after it leaves the blast furnace. Here's how it works:

Why Remove Oxygen?

- Oxygen can react with other elements in steel, forming oxides. These oxides can create weak spots or inclusions in the final product, making the steel brittle and less workable.

The Deoxidation Process:

1. **Adding Deoxidizers:** During tapping, specific metals or alloys called deoxidizers are added to the molten iron. These deoxidizers have a higher affinity for oxygen than iron does.
2. **Chemical Reaction:** The deoxidizers react with the oxygen in the molten iron, forming stable oxides that are often gaseous or have a high melting point.
3. **Separation:** These oxide products either evaporate as gas or rise to the top of the molten iron as slag due to their lower density. The slag can then be removed, leaving cleaner steel behind.

Common Deoxidizers:

- **Manganese (Mn):** A popular and versatile deoxidizer that forms a stable manganese oxide (MnO) that floats as slag.
- **Silicon (Si):** Another widely used deoxidizer, silicon forms a mix of gaseous and slag-forming oxides depending on the amount added.
- **Aluminum (Al):** A very strong deoxidizer that forms a stable alumina (Al_2O_3) inclusion. It's used carefully as too much aluminum can bring back oxygen into the steel.

The Importance of Balance:

Deoxidation is a balancing act. While removing oxygen is essential, using too much deoxidizer can introduce unwanted elements or inclusions as well. We carefully choose the type and amount of deoxidizer based on the desired steel properties.

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Grades of steel with alloy composition

Grade	Type	Composition (wt%)	Properties	Applications
Grade 1	Carbon Steel	Fe (>99%), C (0.25 max), Mn (variable)	Strong, weldable, inexpensive, moderately formable	Construction (beams, frames, fabrication)
Grade 2	Low Carbon Steel	Fe (>99%), C (0.18)	Excellent formability, good weldability, relatively weak	Automotive parts (body panels), appliance sheets, formable applications
Grade 3 (Stainless Steel)	Stainless Steel	Fe (67), Cr (min 10.5), Ni (8)	Excellent corrosion resistance, good formability & weldability	Appliances, kitchenware, medical equipment, architectural applications
Grade 4 (SAE)	Alloy Steel	Fe (90), C (0.4), Cr (1), Mo (0.25)	Good strength, toughness, wear resistance, heat treatable	Aircraft parts, automotive components (gears, shafts), applications requiring balanced strength & toughness
Grade 5	Tool Steel	Fe (99), C (1.5), Cr (0.35), Mn (1.0)	Very hard, wear-resistant	Cutting tools (punches, dies, blades) requiring exceptional edge retention

Recovery rate of alloying elements and its factors

In steelmaking, the recovery rate refers to the **percentage of an alloying element that ends up in the final steel** compared to the amount initially added. It's a crucial factor during alloying because some elements are lost during various stages of the process.

Here's a breakdown of recovery rate and its influencing factors:

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Why Recovery Rate Matters:

- **Cost Control:** Alloys can be expensive, so maximizing the amount that ends up in the final steel is important to avoid waste and keep costs down.
- **Steel Quality:** Achieving the desired properties in the final steel often relies on specific amounts of alloying elements. A low recovery rate can lead to steel that doesn't meet the required specifications.

Factors Affecting Recovery Rate:

- **Oxidation:** When molten steel interacts with oxygen, some alloying elements can oxidize and form slag, which is removed from the steel. Metals with a high affinity for oxygen, like manganese and silicon, are more susceptible to this loss.
- **Volatility:** Some elements have high vapor pressures and can evaporate during high-temperature steelmaking processes. For example, some amount of chromium might be lost due to evaporation.
- **Slag Chemistry:** The composition of the slag can influence the recovery rate of certain elements. By adjusting the slag's chemistry, steelmakers can try to minimize losses.
- **Processing Practices:** The specific methods used during steelmaking can impact recovery rates. Careful handling techniques and optimizing processing times can help minimize losses.

Impact of inclusions in Steel Quality:

The internal cleanliness of steel is determined by

- Composition of the inclusions
- Size of inclusions
- Number of inclusions
- Distribution of its inclusions

Inclusions are compounds such as oxides and sulfides that form in the molten state and solidify in ingots and slabs. Since inclusions are found in all metal alloys, the only question is the severity of the inclusions.

On the basis of size, inclusions are of two types :

Micro inclusion: They have a size range of 1um -100 um

Macro inclusion: They have size of more than 100 um

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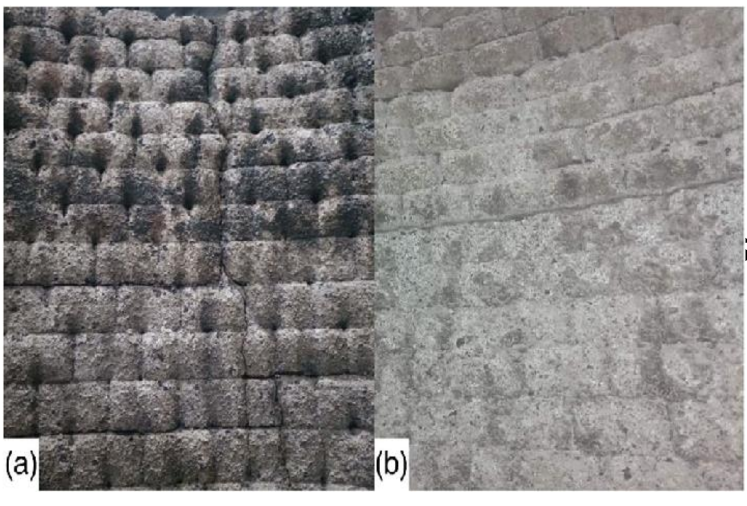
- The presence of inclusions, particularly oxides, sulfides, and nitrides, significantly affects steel's **castability**, which is its ability to flow freely when poured, and its final **functional properties**. These inclusions form throughout various stages of steelmaking, from conversion to casting.
- Oxides are a major concern. They can arise from the reaction between dissolved metals and oxygen within the steel itself or from external sources like the atmosphere, refractories or even the slag layer. Additionally, erosion of these refractories can introduce new inclusions.
- Most oxide inclusions form during the de-oxidation process, where oxygen is removed from the steel, followed by re-oxidation if not controlled properly. To prevent this re-oxidation, various measures are taken, including using shrouds to protect the molten steel stream during transfer, employing high-quality refractory materials, and maintaining a low FeO+MnO content in the slag. Also, ladle refining processes require a slag FeO+MnO content below 1wt% for effective desulfurization and to minimize steel re-oxidation. It is also found that higher FeO+MnO levels can lead to nearly three times more inclusions compared to lower levels.

$$3(FeO) + 2[Al] \rightarrow Al_2O_3 + 3[Fe]$$

$$3(MnO) + 2[Al] \rightarrow Al_2O_3 + 3[Mn]$$

Damage to ladle refractory, primarily occurring at the slag line, necessitates increased maintenance and repair. In the worst-case scenario, such damage can result in melt breakout, posing risks to personnel and equipment. The depth of corrosion in MgO-C refractory increases with higher FeO content in slag and it decreases with higher slag basicity.

FeO speed up the oxidation of carbon on the surface of magnesia-carbon brick. Secondly, FeO reacts with MgO, compromising the structure of the magnesia-carbon brick. When the brick interacts with slag, carbon decarbonizes due to oxides like FeO in the slag, leading to the formation of a decarbonization layer under specific conditions. This results in the weakened structure of the working face of the magnesia-carbon brick, which is the primary cause of its damage. Therefore, reducing FeO content in slag is beneficial for refractory longevity.



OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

The Role of Ferrous Alloys in the Circular Economy

As awareness of the environmental impact of industrial processes continues to grow, the use of materials that can be recycled or reused is becoming increasingly important. Ferrous alloys are ideal for use in the circular economy as they are 100% recyclable and have a long lifespan. In addition, they offer excellent mechanical properties and can be used to create high-quality components.

Sustainable Production and Waste Reduction

As manufacturing point of ferrous alloys, we should be committed to sustainable production and waste reduction. We should implement measures to reduce our energy consumption and minimize our impact on the environment.

Investing in the Future

We believe that investing in the future is essential for the long-term success. That is why we should continually investing in research and development to create innovative alloys that meet the changing needs of people.

Low carbon ferro manganese

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

Ferro silicon

Ferro silico manganese

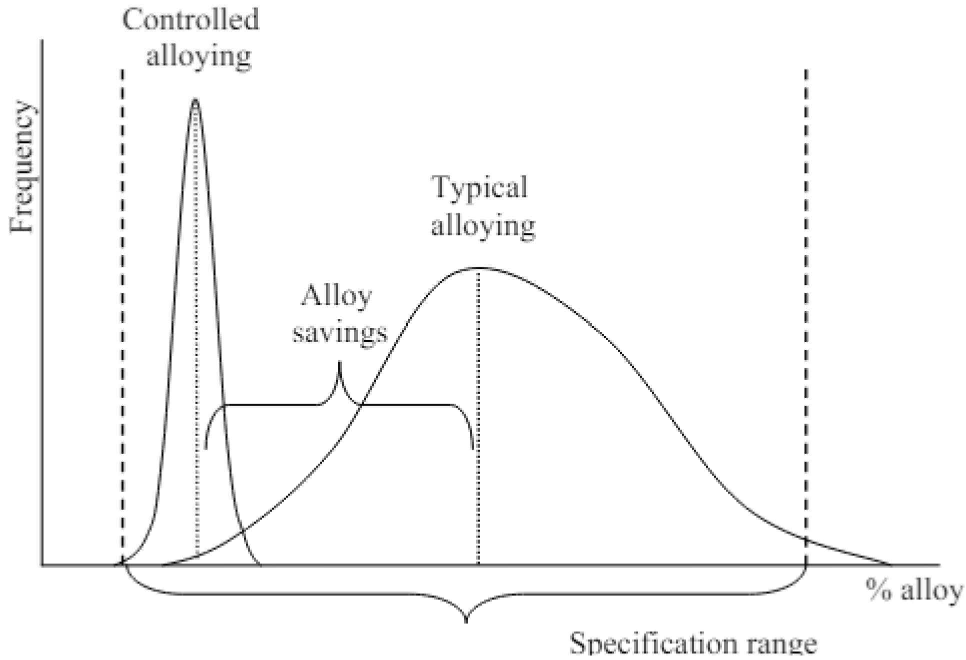
Alloy	Chemical Formula	Reaction in Steel
Ferro-silicon	FeSi	$2FeSi (s) + O_2 (g) \rightarrow 2FeO (l) + 2SiO_2 (l)$
Ferro-silico manganese	Fe + SiMn	$2Mn$ (from FeSiMn) $+ O_2 (g) \rightarrow 2MnO (l)$ Si (from FeSiMn) $+ O_2 (g) \rightarrow SiO_2 (l)$ Mn (from FeSiMn) $+ S (l) \rightarrow MnS (l)$
High carbon Ferro-chrome	HC FeCr	
Low carbon Ferro-chrome	LC FeCr	
Low carbon Ferro-manganese	LC FeMn	$2 Mn$ (from FeMn) $+ O_2 (g) \rightarrow 2 MnO (l)$
High carbon Ferro-manganese	HC FeMn	
Silico-manganese	SiMn	

The recovery of alloying additives depends on the type of furnace and individual foundry practices. EAF operations had greater variations in final chemistry performance than induction furnace operations. Laboratory experiments showed that there is a potential for increased alloy recovery and control through argon stirring with a porous plug. Argon stirring decreased mixing time by 50% and decreased the local variation in steel composition.

Recovery of additives depends on a vast spectrum of parameters, summarized in three groups:

1. Type of additives (concentration of the alloying elements and their chemical activity, in particular, affinity to oxygen, density, size and shape of particles, concentration of impurities).
2. Methods of alloying (in furnace or ladle, special injection methods, such as wire injection, in stream or in the mold treatments, intensifiers of dissolution by mixing).

3. Melting techniques (type and size of melting furnaces, slag composition, condition, and quantity, temperature of melt, melting period).



Oxidation of the alloy is usually the primary cause of poor or erratic recovery. It was found that increasing the dissolved oxygen in the steel lowered the alloy recovery and decreased the dissolution rate of alloys with melting points greater than steel. The reduction in dissolution rate was attributed to the possible formation of a refractory oxide on the alloy surface. Important sources of oxygen are furnace slag and air contact. Other sources of oxygen include slag remaining in the furnace (or ladle) from previous heats, oxygen dissolved in the metal, air carried into the melt by alloy additions, and from refractory-metal interactions.

In order to transfer alloying elements to the molten steel bath, it is first necessary to immerse the ferroalloy into the metal. Upon addition, a steel shell is frozen on the surface of the alloy. Heat transferred from the molten bath remelts this shell back to the original alloy surface.Superheat and bath stirring plays an important role in alloy . Melting point is the primary factor in dissolution rate, while other important properties include density, thermal conductivity, specific heat, and enthalpy of mixing(the rate of dissolution, which measures how fast a solute dissolves in the solvent, mainly depends on the frequency of collision between the solute and solvent molecules). Density determines whether the addition will float (ferrosilicon), sink (ferromanganese) or be entrained within the melt (ferrochromium). Thermal conductivity, along with specific heat and density, determines the thickness of the steel shell, which forms on the cold addition. Finally, a strong exothermic reaction between the alloy and steel (enthalpy of mixing) can substantially reduce the assimilation time (75% ferrosilicon).

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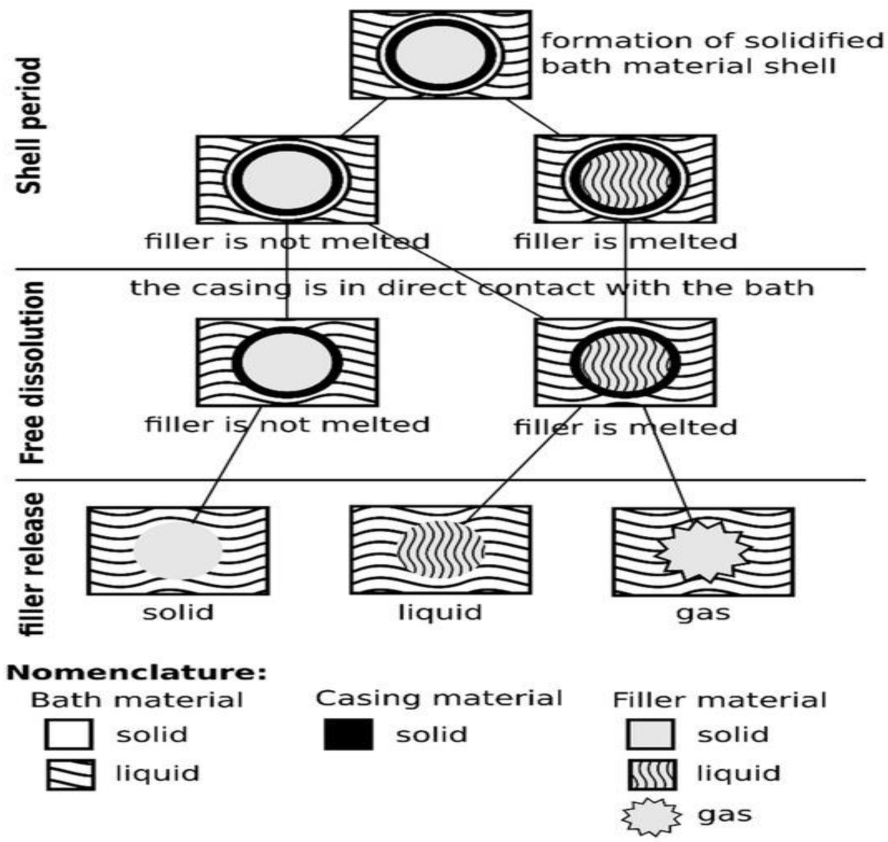
We can understand about assimilation time with an example of cored wire. Cored wire is produced by tightly wrapping and sealing a metal sheet (casing) around a core of material, for instance, Ca, CaSi, CaFe, FeTi, Ti, FeB, FeV, FeNb, C, S, FeS, Al, etc.. The wire is coiled into a payoff reel or a coil and is then fed into a molten metal bath by means of wire feeding equipment, which uses a series of pinch rolls to uncoil the wire and to push it through a guiding tube into the molten metal . Cored wire injection is especially practiced for elements that are less dense than the molten metal and/or that have a limited solubility, high vapor pressure, and/or high oxygen affinity. It is also used in situations where the added materials are toxic. The assimilation time-span is characterized by two distinct periods: the shell period, controlled by heat-transfer phenomena, in which a shell of bath material solidifies around the "cold" body and then is melted back as the immersed body is heated up; and the free-dissolution period, taking place once the "heated" body comes into direct contact with the bath, eventually dissolving, and this period can be controlled by heat-transfer or mass-transfer. Assimilation not only depend on the combination of the physical properties of the pair of immersed solid and liquid metals, but also on the flow conditions and bath superheat. The different wire assimilation routes are a function of the wire design parameters(e.g., wire core an (e.g., bath material, bath superheat, wire injection speed) and processing condition e.g.(bath material, bath superheat and wire injection speed)



OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

Minimizing alloy size improves dissolution rate, which is contrary to historical practice where large lumpy ferroalloys were employed to aid in penetrating the slag layer. Unfortunately, small size means more surface area on which to transport undesirable gases and moisture, plus, small alloy size increases dust losses and incurs handling difficulties. It is determined that the optimum size for bulk materials is between 3 and 20 mm in diameter. Wire and powder injection are both means of overcoming limitations imposed by fine alloy size. Efficient steelmaking processes rely on the motion of molten steel to:

1)dissolve alloys
2)float inclusions
3)eliminate chemical inhomogenities
4)eliminate temperature inhomogenities

Natural forces can induce steel motion, e.g. convection due to temperature gradient or energy of the falling stream during tap. Natural convection is relatively slow; while tap induced motion is time limited. In contrast, external forces, like induction stirring in induction furnaces, or gas injection through a lance, plug, or tuyere can create significantly more intense motion. Gas injection via lances and porous plugs is the predominant method of stirring used in wrought steel production.

ELLINGHAM DIAGRAM:

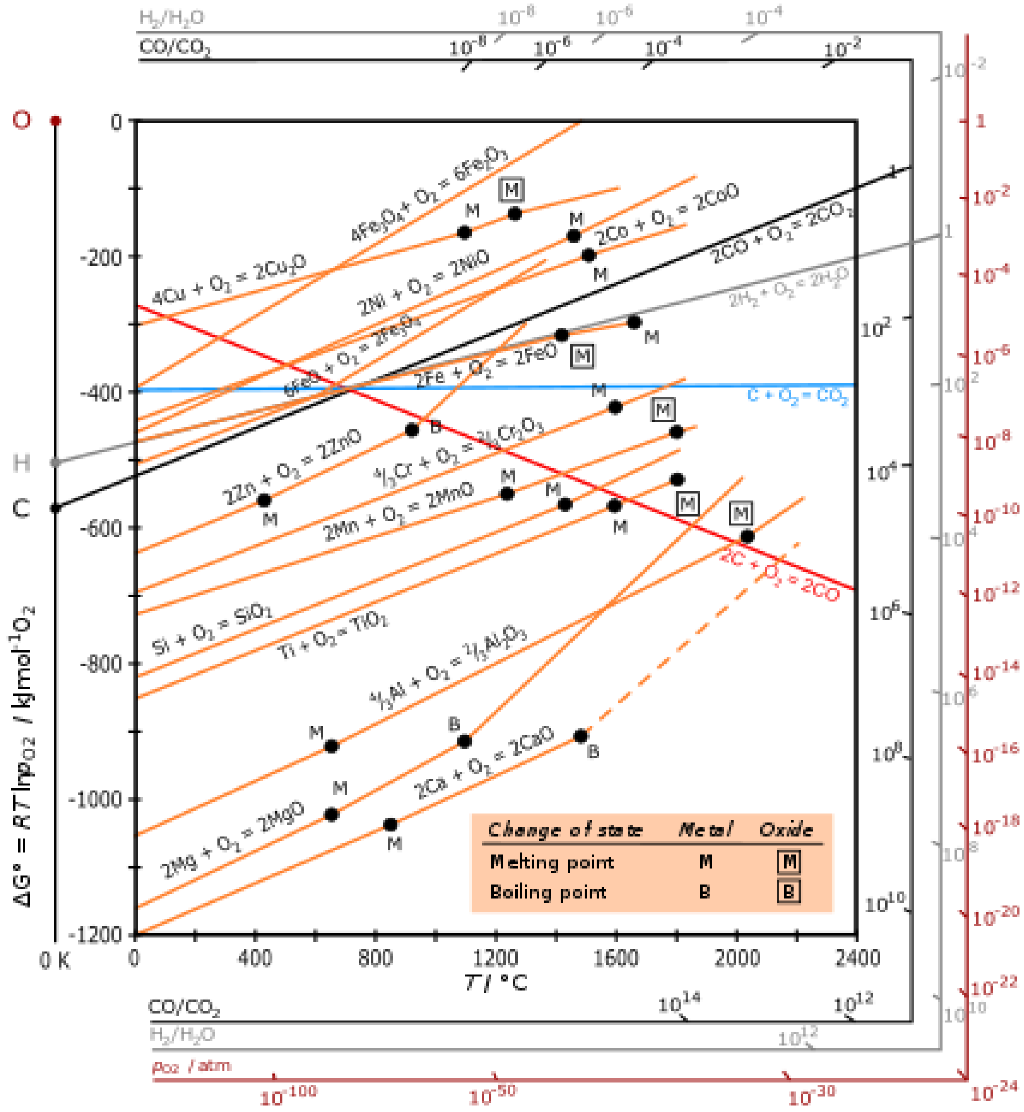
An **Ellingham diagram** is a graph showing the temperature dependence of the stability of compounds. This analysis is usually used to evaluate the ease of reduction of metal oxides and sulfides. These diagrams were first constructed by Harold Ellingham in 1944.[1] In metallurgy, the Ellingham diagram isused to predict the equilibrium temperature between a metal, its oxide, and oxygen — and by extension,reactions of a metal with sulfur, nitrogen, and other non-metals. The diagrams are useful in predicting the conditions under which an ore will be reduced to its metal. The analysis is thermodynamic in nature and ignores reaction kinetics. Thus, processes that are predicted to be favourable by the Ellingham diagram can still be slow.

1. Curves in the Ellingham diagrams for the formation of metallic oxides are basically straight lines with a positive slope. The slope is proportional to ΔS, which is practically constant with temperature.
2. The lower the position of a metal's line in the Ellingham diagram, the greater is the stability of its oxide. For example, the line for Al (oxidation of aluminium) Is found to be below

that for Fe (formation of Fe_2O_3).

3. Stability of metallic oxides decreases with increase in temperature. Highly unstable oxides like Ag_2O and HgO easily undergo thermal decomposition.
4. The formation free energy of carbon dioxide (CO_2) is almost independent of temperature, while that of carbon monoxide (CO) has negative slope and crosses the CO_2 line near 700 °C. According to the Boudouard reaction, carbon monoxide is the dominant oxide of carbon at higher temperatures (above about 700 °C), and the higher the temperature (above 700 °C) the more effective a reductant (reducing agent) carbon is.
5. If the curves for two metals at a given temperature are compared, the metal with the lower Gibbs free energy of oxidation on the diagram will reduce the oxide with the higher Gibbs free energy of formation. For example, metallic aluminium can reduce iron oxide to metallic iron, the aluminium itself being oxidized to aluminium oxide. (This reaction is employed in thermite.)
6. The greater the gap between any two lines, the greater the effectiveness of the reducing agentcorresponding to the lower line.
7. The intersection of two lines implies an oxidation-reduction equilibrium. Reduction using a given reductant is possible at temperatures above the intersection point where the ΔG line of that reductant is lower on the diagram than that of the metallic oxide to be reduced. At the point of intersection, the free energy change for the reaction is zero, below this temperature it is positive and the metallic oxide is stable in the presence of the reductant, while above the point of intersection the Gibbs energy is negative and the oxide can be reduced.

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING



Ferroalloys

Ferroalloys are a group of alloys of iron containing one or more additional elements other than carbon. Ferroalloys have a high percentage of such elements as manganese, silicon, chromium, and aluminium etc. Ferro-alloys are mainly used as master alloys used in the iron and steel industry since it is the most economical way to introduce an alloying element into the steel melt. These alloys are incorporated into the molten stage of the steelmaking process for the purpose of producing specific properties in the steel. Ferroalloys industry is very closely related to iron and steel industry since ferroalloys are used extensively in steelmaking, and in iron or steel foundries. Ferroalloys are the integral constituents of any steelmaking process, as these are indispensable materials for refining, deoxidation, desulphurization, and alloying to achieve the desired chemical and physical properties in steel.

As such they influence the steel quality and steelmaking economics to a great extent. They are vital inputs for producing all types of steel and are used as raw material in the production of alloys steel and stainless steel. Not a single grade of steel is produced without ferro-alloys. In fact, more than 85 % of ferroalloys produced globally are consumed in the steel industry Ferroalloys are important additives which are used in steelmaking as deoxidants and also as alloying elements.

These are added in steel production not only for de-oxidation but also for grain size control for improvement in the mechanical properties of steel. Depending upon the process of steelmaking and the type of steel being made, the requirement of different ferroalloys varies widely. The principal function of ferroalloys addition to steel increases its resistance to corrosion and oxidation, improve its hardenability, tensile strength at high temperature, wear and abrasion resistance with added carbon and increases other desired properties in the steel such as creep strength etc. The effect of the improved properties of steel by using ferro-alloys as an alloying element depend more or less on such influences as: (i) a change in the chemical composition of the steel (ii) the removal or the tying up of harmful impurities such as oxygen, nitrogen, sulphur or hydrogen, (iii) a change in the nature of the solidification, for example, upon inoculation. Ferroalloys have a high content of the major component, typically in the range of 50 % to 90 %, the rest being mostly iron and more or less 'residues' of reductants used in ferroalloy production (carbon, aluminium, and silicon depending on the process).

How these components are limited in ferroalloys depends on the targeted analysis range. Such metallic impurities can have special limitations due to their influence on oxide inclusions or other precipitates (nitrides, carbides). Ferroalloys also contain small amounts of impurities Sulphur, phosphorus, gases (oxygen, nitrogen, and hydrogen etc.), and moisture. Historically, the ferro-alloy production technology used in the 19th century was developed for blast furnaces, which at that time was the main process for the production of cast iron. In a blast furnace, however, it is not possible to produce ferro-alloys with elements which have a higher affinity for oxygen or with low carbon content. This led to the development, at the beginning of the 20th century, of ferroalloys to be manufactured (smelted) in electric furnaces. These days almost all ferro-alloys are produced in the submerged arc furnaces. These furnaces are either open or semi-open (hooded furnace allowing the entry oxygen) or closed (hermetic system) types, depending on the production requirements for the various ferro-alloys

A. Ferro-Manganese

Ferro-manganese (Fe-Mn) is a metallic ferro alloy which is added normally along with ferro-silicon as ladle addition during steelmaking. It is a ferroalloy composed principally of manganese and iron, and normally contains much smaller proportions of minor elements, such as carbon, phosphorus, and Sulphur. Fe-Mn is an important additive used as a deoxidizer in the production of steel. It is a master alloy of iron and manganese with a minimum manganese content of 65 % and maximum content of 95 %. Fe- Mn is a ferroalloy with high content of manganese. It is produced by heating a mixture of the oxides of manganese (MnO_2) and iron (Fe_2O_3) with carbon normally as coal and coke, in either a blast furnace or a SAF. The oxides undergo carbo thermal reduction to produce Fe- Mn. It is produced as three types of products namely (i) standard high carbon Fe-Mn, (ii) medium carbon Fe-Mn and (iii) low carbon FeMn.

High carbon Fe-Mn has manganese in the range of 72 % to 82 %, carbon in the range of 6 % to 8 %, and silicon in the range of around 1.5 %. Medium carbon Fe-Mn has manganese in the range of 74 % to 82 %, carbon in the range of 1 % to 3 % and silicon in the range of around 1.5 %. Low carbon Fe-Mn has manganese in the range of 80 % to 85 %, carbon in the range of 0.1 % to 0.7 % and silicon in the range of 1 % to 2 %. Manganese plays an important role in the manufacturing of steel as deoxidizing, desulphurizing, and alloying agent.

It is a mild deoxidizer than silicon but enhances the effectiveness of the latter due to the formation of stable manganese silicates and aluminates. It is used as an alloying element in almost all types of steel. Of particular interest is its modifying effect on the iron-carbon system by increasing the hardenability of the steel. By adding the manganese as medium carbon Fe-Mn or low carbon Fe-Mn instead of high carbon Fe-Mn, around 80 % to 93 % less carbon is added to the steel. Nitride medium carbon Fe-Mn contains a minimum of 4 % of nitrogen. Fe-Mn is produced in a number of grades and sizes and is consumed in bulk form primarily in the production of steel as a source of manganese, although some Fe-Mn is also used as an alloying agent in the production of iron castings. Manganese, which is intentionally present in nearly all steels, is used as a steel desulphurize and deoxidizer. It improves the tensile strength, workability, toughness, hardness and resistance to abrasion. By removing Sulphur from steel, manganese prevents the steel from becoming brittle during the hot rolling process.

B. Silicon-Manganese

Si-Mn is a ferroalloy composed principally of manganese, silicon, and iron. It normally contains much smaller proportions of minor elements, such as carbon, phosphorus, and sulphur. The ferroalloy is also sometimes referred to as ferro-silicon-manganese. It is being used to add both silicon and manganese as ladle addition during steelmaking. Si-Mn is produced in a number of grades and sizes and is consumed in bulk form primarily in the production of steel as a source of both Si and Mn, although some Si-Mn is also used as an alloying agent in the production of iron castings. Because of its lower carbon content, it is a preferred ladle addition material during making of low carbon steels. Both manganese and silicon play an important role in the production of steel as deoxidizing, desulphurizing, and alloying agents. Si-Mn adds additional silicon in liquid steel which is a stronger deoxidizer and which also helps to improve some mechanical properties of steel.

Si-Mn with high content of manganese and silicon is produced by heating a mixture of oxides of manganese (MnO_2) silicon (SiO_2), and iron (Fe_2O_3) with carbon in a furnace. These oxides undergo a thermal decomposition reaction. The standard grade contains manganese in the range of 62 % to 68 %, silicon in the range of 12 % to 18 % and carbon in the range of around 2 %. The low carbon grade of SiMn has a carbon level of 0.1 % maximum. Si-Mn is more preferred ferroalloy by the steel melting shop operators for deoxidation. The steel industry is the only consumer of these alloys. To cover the need for Mn and Si, the steelmaker has the choice of a blend of Si-Mn, high carbon Fe-Mn and Fe-Si governed of by specifications on carbon, silicon, and manganese. Normally earlier a mixture of high carbon Fe-Mn and Fe-Si were used, but now a trend towards more use of Si-Mn is seen at the expense of the two others. This is primarily for economic reasons. Effects of the addition of Si-Mn to steel depend on the amount added and the combined effect with other alloying elements. Both Si and Mn have an important influence on the properties of steel since both of them have a strong affinity for oxygen, and act as deoxidizers. Deoxidation with Si-Mn results in cleaner steel, as the liquid manganese silicate formed coagulates and separates easier from the melt, compared to solid SiO_2 formed during Fe-Si deoxidation. Use of Si-Mn adds less carbon to steel compared to combination of standard Fe-Si and high carbon Fe-Mn. Computational fluid dynamics calculations show that the yield of silicon from Si-Mn is higher than that of the standard Fe-Si.

C.Ferro silicon

Ferro-silicon (Fe-Si) is a metallic ferro-alloy having iron and silicon as its main elements. In commercial terminology, it is defined as a ferro-alloy containing 4 % or more of iron, more than 8 % but not more than 96 % of silicon, 3 % or less phosphorus, 30 % or less of manganese, less than 3 % of magnesium, and 10 % or less any other element. However, the regular grades of the ferroalloy normally contain silicon in the range of 15 % to 90 %. The normal silicon contents in the Fe-Si available in the market are 15 %, 45 %, 65 %, 75 %, and 90 %. The remainder is Fe and minor elements. The minor elements, such as aluminium, calcium, carbon, manganese, phosphorus, and Sulphur are present in small percentages in Fe- Si. Fe-Si is normally used along with Fe-Mn as ladle addition during steelmaking. Commercially, Fe-Si is differentiated by its grade and size. Fe-Si grades are defined by the percentages of silicon and minor elements contained in the product. The principal characteristic is the percentage of silicon contained in the ferro-alloy and the grades are referred to primarily by reference to that percentage. Hence 75 % Fe-Si contains around 75 % of silicon in it.

Fe-Si grades are further defined by the percentages of minor elements present in the product. ‘Regular grade 75 % Fe-Si’ denote that the product contains the indicated percentages of silicon and recognized maximum percentages of minor elements. Other grades of Fe-Si differ from regular grades by having more restrictive limits on the content of elements such as aluminium, titanium, and / or calcium in the ferro-alloy. Fe-Si is also produced in a grade which contains controlled amounts of minor elements for the purpose of adding them to steel or foundry iron using Fe-Si as the carrier. Such Fe-Si products are sometimes called ‘inoculants. Fe-Si is normally produced in four grades. These are (i) standard grade, (ii) low aluminium grade, (iii) low carbon grade, and (iv) high purity grade having low content of titanium. The standard grade of FeSi contains aluminium up to 2 % while the low aluminium grade has aluminium content of 0.5 % maximum. Fe-Si contains a high proportion of iron silicide. Fe-Si with 15 % silicon is not used for metallurgical purposes in the production of steel or cast iron. Specialty grade 15 % Fe-Si is combined with water to create a dense medium for gravity (sink / float) separation of minerals, aggregates, and metals. Fe-Si is mainly used during steelmaking and in foundries for the production of carbon steels and stainless steels as a deoxidizing agent, for the alloying of steels, and cast iron. It is used as a reducing agent, particularly in the production of stainless steel.

As a reducing agent, silicon reacts with chromium oxides to form silicon oxides, returning chromium to the liquid steel, and thus increasing the overall chromium recovery of the process. Fe-Si is also used as the source of silicon for alloying purposes in the production of certain steel alloys, particularly silicon electrical steel, which can contain 3 % or more of silicon. Fe-Si is used by iron foundries as the source of silicon needed for alloying purposes in iron castings. During the production of cast iron, it is also used for inoculation of the iron to accelerate graphitization. In arc welding, Fe-Si can be found in some electrode coatings. Almost all Fe-Si consumed in the steel and cast-iron industry contains silicon ranging from 65 % to 90 %. Fe-Si is used primarily in sized lump form. Size is important since it affects the performance of the Fe-Si in its designated use. Large lumps are normally used in primary steelmaking furnaces since they penetrate the layer of slag on top of the liquid steel more readily. Smaller lumps are more commonly used for alloying purposes to ensure rapid dissolution in liquid steel. Fines are less desirable than lumps since it is more difficult to recover the silicon content in them.

Observation

To optimize the ferro-alloy consumption:

OPTIMIZATION OF FERRO ALLOYS IN STEEL MAKING

- **Reduce reblow:** if endpoint temperature and component of molten steel do not approach the target value then we have to reblow, the molten steel to adjust the temperature and composition of steel. During reblow,majorly oxygen react with Fe and C. If reblow exceeds it suitable limit then it react with carbon which forms CO which in turn form CO_2 and it also increases the amount of oxygen in the molten metal.The increased oxygen reacts with the ferro alloys and form their oxides, resulting in the increased consumption of ferro alloys.

- **Addition of coke bag:** At the beginning of tapping of molten metal, we add some bags of coke in laddle so that the oxygen present in the molten metal will react with coke and form CO_2 in order to lowered the oxygen level of molten metal and hence decrease in ferro alloy consumption.

- **Blow termination point:** The blow should be terminated by analysing the off gas volume and CO composition in off gas. When the CO composition is less than a certain level, it indicates that the carbon content is low in bath and further blowing will just increase the oxygen level therefore increase the consumption of ferro alloy.

- **Yield weight should be considered:** The heat weight of molten steel tapped in the ladle from converter is varying which affects the consumption of ferro alloy . So to ensure the optimum use of the ferro alloys, consistency in heat weight is required.